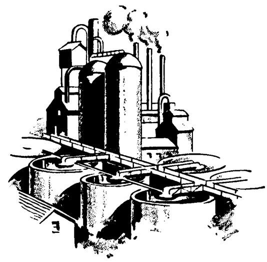


chapter 3

The Various Engineering Departments

WE WILL consider the engineer's fields of work from three points of view. First, there is the familiar division by *departments,* such as Civil, Electrical, Mechanical Engineering. Second, we have classification by *industries,* such as automotive, agricultural machinery, construction, public utility, paper making, steel, textile. Third, we can classify the engineer's work according to the *function,* or special purpose, that is performed, such as design, construction, development, research, and selling.

The best-known classification of the engineer's work is that which groups it by degree-granting departments. In these departments the courses of study, commonly known as curriculums, grow out of the special technical needs of the engineers who practice in the designated field. In most engineering colleges of the United States the standard college curriculum which leads to the B. S. in a named branch of engineering consists of four years, each nine months in length.

In many of these colleges the courses of the first year are the same for all engineering curriculums, and include mathematics, chemistry, English, and engineering drawing. The curriculums begin to diverge in the second year. There is still a common core of mathematics, physics, and mechanics, and the beginning of course work of the major department, such as surveying for Civil Engineering, more chemistry for Ceramic and Chemical Engineering, machine shop and metallurgy for Mechanical Engineering. The number of courses of the major department increases in the third year, and in the fourth year there are few courses outside the major department. Various agencies, particularly the American Society for Engineering Education (ASEE) and Engineers Council for Professional Development (ECPD), have tried to maintain some uniformity in the engineering curriculums by specifying a percentage of course work that should be in each of the several areas of fundamental science, engineering science, humanistic-social studies, and the major field.

The Journal of Engineering Education Yearbook for 1955 gives enrollment and graduation figures for 19 curriculums, and the ECPD Preliminary Annual Report for the year ending September 30, 1955, lists 19 accredited engineering curriculums. These are: aeronautical, agricultural, architectural, ceramic, chemical, civil (including building engineering and construction, sanitary, structural), electrical, engineering, engineering mechanics, engineering physics, geological, geophysical, industrial (including options in mechanical engineering departments), mechanical, metallurgical, mining, naval architecture and marine, petroleum (including petroleum refining, petroleum production, petroleum and natural gas), textile engineering.

This continual splitting of Engineering into more curriculums is receiving increasing and critical attention of ECPD and the National Council of State Boards of Engineering Examiners. In the preliminary report referred to above it is stated that "ECPD continues to favor the general policy of minimizing the number of specially designated curricula, endorsing whenever practicable the utilization of options in major curricula (as Sanitary Option in Civil Engineering) to designate specialization. It is, however, prepared to examine for approval any curriculum that appears likely to satisfy its criteria for an undergraduate engineering curriculum."

The 1955 ECPD Preliminary Report presents some supplemental criteria that have as their object "the assurance of an adequate foundation in science, humanities, engineering science, and introduction to engineering method while providing sufficient flexibility in science requirements to accommodate curricula requiring special backgrounds, such as life science or earth science. They also provide substantial flexibility for expression of the institution's own individuality and ideals. Finally they are regarded as a statement of principles to be applied with judgment in either case rather than with arbitrary rigidity."

That preliminary report then states these supplemental criteria:

a. All curricula shall contain at least the equivalent of one academic year of mathematics and basic science about equally divided.

b. Except as provided in (c) all curricula shall contain at least the equivalent of approximately one year of engineering sciences, including the following:

1. Mechanics of solids (statics, dynamics, strength of materials)
2. Fluid mechanics
3. Thermodynamics
4. Transfer and rate mechanisms (heat, mass, momentum transfer)
5. Electrical theory (fields, circuits, electronics)
6. Nature and properties of materials (relating particle and aggregate structure to properties)

c. Because some engineering curricula are built in part on sciences not included in the preceding paragraphs, such curricula may contain for additional flexibility other basic or engineering sciences appropriate to their fields, to an extent equivalent to one-third of an academic year, in lieu of an equal portion of time otherwise devoted to the engineering sciences listed in [b above].

d. Approximately the equivalent of one-half of an academic year shall be devoted to engineering analysis, design, and engineering systems.

e. The curriculum shall be designated for an integrated sequential study in the scientific and engineering area. The mathematics and the basic science to be used proficiently in the work in engineering analysis, in the study of engineering systems, and in the preparation for creative design.

f. Depending upon the definition of humanistic-social studies, the equivalent of one-half year to one full year of the curriculum shall represent the minimum content in this area. Of this content, at least one-half year shall be selected from the fields of history, economics, government, literature, sociology, philosophy, psychology, or fine arts, and should not include such courses as accounting, industrial management, finance, personnel administration or ROTC.

We will not have time or space to discuss all of the engineering curriculums that are available in the engineering schools of the United States. So, we will choose those of the founder societies and several others that have become well established in many engineering schools and colleges. This list includes aeronautical, agricultural, architectural, ceramic, chemical, civil, electrical, industrial, mechanical, metallurgical and mining.

In this discussion the reader should keep in mind the fact that our purpose is to describe the work and requirements of each department so that the points in which it differs from other departments will be as clear as possible. There are areas that are common to several departments, and men who receive their degrees in one field often take jobs that are commonly listed in another field. For example, large numbers of civil and mechanical engineering graduates are working for aircraft manufacturing companies, and agricultural engineering graduates are found in public works in the field of the civil engineering graduate. There are characterizing differences among these fields of engineering which the prospective engineering student should understand if he expects to base his choice of a curriculum on anything more than chance. And the successful engineer in a given field should have the traits common to all engineers as well as those characteristic of his special field.

AERONAUTICAL ENGINEERING

Aeronautical engineering is one of the most recent of the engineering curriculums. Also, developments in aircraft structures, engines, and materials have been very rapid. All of this, plus romantic interest, plus contact with military airplanes, has turned many young men to this field. However, the profession and industry are now far advanced byond the early days when the progress of flying depended upon adventurous and gifted men. Those who succeed in the technical phases of aeronautics must have a thorough engineering education.

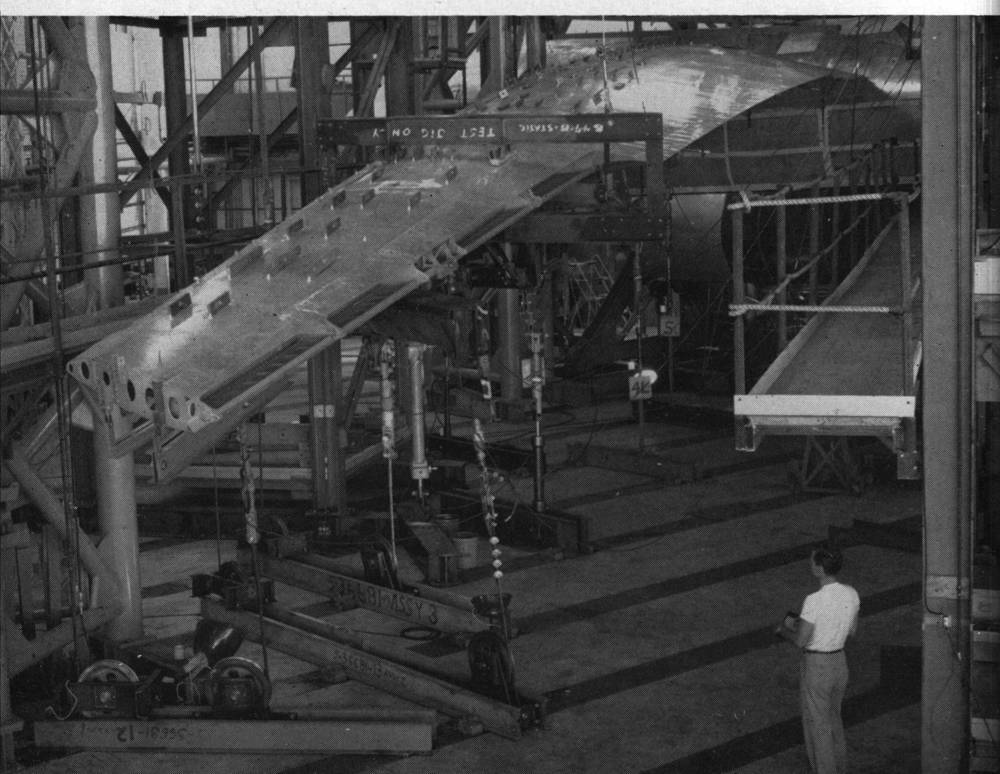
Most of the great developments in this field have come in the twentieth century, many of them during and after World Wars I and II. Since the second war, in particular, huge sums of money have been spent by the government and by private agencies on analytical and experimental studies that have brought bigger, faster, new-type aircraft structures, new and stronger alloys of metals, new types of power plants, and extensive improvements in the older types. Growth of the airplane from the little monoplane and biplane to the huge many-engined passenger- and freight-carrying ship of today is well known to anyone who looks at a television program. But what is not so well known, and of great significance to the would-be aeronautical engineer, is the important part that engineers have played in this development. By extensive research, improved design and better production methods, they have moved the airplane from a custom-made, individually-laid-out machine into a production line creation. The airplane of the future will be designed and built by engineers who know, in addition to the basic engineering courses, mathematics beyond calculus, advanced chemistry and physics, advanced aerodynamics and thermodynamics, indeterminate structures, and advanced properties of materials.

Our picture of the successful aeronautical engineer does not include the ability to pilot an airplane — although this is a useful ability — nor airport construction, nor the business of air transportation. What he does expect to do is to create, design, develop, and build airplanes. As he looks into the requirements he sees a profession that is still in the process of establishing its boundaries. He sees in the airplane a complex structure whose planning, design, and manufacture call for the solution of difficult problems in stress analysis, fluid flow, aerodynamics, and production methods. This structure is driven through the air by an intricate power plant, conventionally a rotating internal-combustion engine, and, recently, a jet engine. Inside the plane are innumerable devices that are used to send and receive signals, to control the plane, to guard against accidents, and to do many other things. Clearly, the man who would have some responsibility for the design of a complete airplane must study many engineering courses in college. And if he wishes to have a place in the manufacturing of planes he must also know a great deal about production and manufacturing processes.

Fields of Aeronautical Engineering

Most aeronautical engineers take jobs in areas related to the aircraft industry. This includes employment with the federal government and with private companies. The former has very extensive research laboratories and pilot plants where all types of studies are carried on. Also, private companies and universities have large government contracts whose objective is the development and improvement of such devices as aircraft and guided missiles. With both of these the emphasis is on research in such fields as Aerodynamics, Hydrodynamics, Propulsion, Aircraft Loads, Airframe Construction and Materials, Flight and Pilotless Airplanes. Some of this work is done on the drafting board, in the calculating room, in wind tunnels, or on the airplane in flight. In every instance men are needed who have above-average ability in the mathematical and physical sciences.

An engineer observes the static test on an airplane during the wing-bending phase of the program. Note devices for applying loads. The wing tip went through an arc totaling 32 feet during the tests. (Courtesy Boeing Aircraft Co.)



The production line at an aircraft plant shows several twin jet fighters being fabricated in the final assembly area. In addition to planning and designing the aircraft, the engineer supervises its manufacture. (Courtesy McDonnell Aircraft Co.)

Similarly, the aircraft manufacturing companies have places for men who will work on the design and production of planes that are to be built, as well as on research and development. Here the aeronautical engineer does such work as: Aerodynamics — performance calculations, stability, control, and flight test analyses; Flight Tests — both operations and instrumentation; design of fuselage structure and wing structure; for Structures — check of drawings, computation of stress analyses, evaluation of new materials; in Production — selection and design of tools, assembly line planning, and use of proper tools.

Characteristics of Aeronautical Engineers

The successful aeronautical engineer should have the following traits: (1) ability to visualize; (2) better-than-average mechanical ability; (3) better-than-average aptitude for mathematics and the physical sciences; (4) the type of mind that can work well with both the abstract and the concrete

Professional Organization for Aeronautical Engineers

The Institute of Aeronautical Sciences, which was founded in 1932 and patterned after the Royal Aeronautical Society of Great Britain, is the professional society for aeronautical engineers. Its objective is to advance the art and science of aeronautics. Membership in the organization begins with the grade of Technical Member. Such members shall be former student members who have graduated and others engaged in scientific or engineering work in aeronautics, or fields closely related to aeronautics.

The institute has approximately 70 student branches in the United States. Membership in a student chapter (student member) calls for no dues, and entitles the student to subscribe for the Review (technical publication of the institute) at half price. Upon graduation the student member may become a technical member by paying annual dues. There is no entrance fee.

AGRICULTURAL ENGINEERING

An agricultural engineer is one who devises and utilizes machinery for multiplying man's power in the agricultural industry, which is the industry engaged in the production of raw materials used for food, shelter, and clothing. Agricultural engineering had its beginning as a department of farm mechanics in agricultural colleges. It is still closely allied with agricultural education, and in many colleges the department of Agricultural Engineering is administered jointly by the deans of Agriculture and Engineering. This dual relationship and responsibility has posed many problems of curriculum content and organization as the department has moved forward in its program to achieve recognition as a professional engineering department. By 1954 it had been accredited by ECPD in 24 colleges of the country.

The application of engineering methods in agriculture, often referred to as mechanization, has brought immeasureable benefits. Among these are: (1) increased productive capacity of the farm worker, (2) change of the character of labor on the farm, (3) aid in shortening the average length of the working day, (4) contribution to the comfort, health, and convenience of farm life, (5) sharp reduction of women as laborers in the field.

Three notable milestones in the mechanization process have been Eli Whitney's cotton gin, which made a change in the processing or manufacturing of a product already harvested; McCormick's mowing machine, which was the first machine with moving parts that moved in a field; McCormick's harvester, which carried the grain until a sheaf had accumulated, then bound it and kicked it off. These machines released men from hand labor with scythes and rakes.

The next and perhaps greatest advance in the application of power to the farm has followed the development, adaptation, and quantity production of the internal combustion engine, first the gasoline engine and later the diesel engine. Here the source of power is the fuel which runs the engine which, in turn, propels the machine over the ground and, at the same time, furnishes power to do the work of picking corn, baling hay, threshing grain, and many other operations.

It is obvious that the credit for these mechanical developments must be shared by many engineers, manufacturers, farmers, implement dealers, and others. Also, there is a fairly clear line between the interests and functions of the agricultural and mechanical engineers in this development. The latter is concerned with development, design, manufacturing, and applications to uses that are primarily industrial. The agricultural engineer is interested in those phases of development and design that relate to the application of power to agricultural uses. Generally, the actual manufacturing processes are handled by mechanical engineers.

Development of farm equipment requires actual testing under operating conditions. Here, an agricultural engineer is making field tests on a new type of forage harvester, using electrical resistance strain gauges and electronic recording equipment.

Fields of Agricultural Engineering

The fields of specialization of agricultural engineering departments for purposes of optional undergraduate work, graduate work, research, field service, etc., are divided into Farm Power and Machinery, Farm Structures, Rural Electrification, Soil and Water Conservation. In many curriculums a group of technical electives is designated for students who wish to specialize in one of these areas.

Farm Power and Machinery. Courses in preparation for this option include Kinematics, Machine Analysis, Design of Machine Elements, and Agricultural Machinery Design. Those who work in this field are engaged in the design of machines, and the selection and efficient application of power to the farm through various pieces of mechanical equipment, as well as the sale and servicing of these implements. The annual bill for the purchase of farm machinery is large, and the depreciation is rapid. Companies that manufacture and sell farm equipment employ agricultural engineers to work with the sellers and users of this equipment to improve the product and its service and to lengthen its life.

Farm Structures. Courses in preparation for this option include Heat Transfer, Refrigeration and Air Conditioning, and Elements of Structures. Work includes the planning and construction of farm buildings, and providing the water, light, heat, sewage disposal, and ventilating systems for these buildings and related farm operations. Timber, concrete, steel, aluminum, and other materials in new and improved designs are in use on the farm for houses, barns, hog houses, chicken coops, and other buildings. Water from wells and farm ponds is piped into the house, barn, and feed lot. Sewage must be disposed of sanitarily in septic tanks.

Rural Electrification. Courses for this option are similar to those for the Farm Structure option with Application of Electronics replacing Elements of Structures. Perhaps the most striking change in farm living has come about through increased use of electricity. Agricultural engineers who work on rural electrification have the task of utilizing this power effectively in the rural community.

Soil and Water Conservation. Special courses in this area are Design of Soil and Water Conservation Facilities, Soil Conservation and Erosion Control, and Soil Engineering. The work includes drainage, irrigation, land clearing, erosion control, and the necessary surveying. This activity of agricultural engineers has received nationwide impetus and publicity durng the last twenty-five years. We must conserve our natural resources, and soil and water are two of the most important. Employment in this field is largely by the state and federal governments.

Characteristics of Agricultural Engineers

The young man who plans to make agricultural engineering his career should possess the following specific characteristics, in addition to those listed for all engineers: (1) a definite interest in farm life and sympathetic understanding of agricultural problems; (2) an interest in and liking for courses in agriculture; (3) a preference for the experimental and practical aspects of engineering rather than the theoretical and technical, because in the applications of power to the farm there is much that is "cut and try"; (4) a liking for outdoor life on the farm, because agricultural engineers will find their work close to the farm whether it be with machinery, structures, rural electrification, or soil and water conservation.

Professional Organization for Agricultural Engineers

The American Society of Agricultural Engineers is the professional organization for agricultural engineers. Its objects as given in the constitution are: "To promote the science and art of engineering as applied to Agriculture; to encourage original research; to foster agricultural engineering; to advance the standards of agricultural engineering; to promote the intercourse of agricultural engineers among themselves and with allied technologists; to encourage the professional improvement of its members; and severally and in cooperation with related groups to broaden the usefulness of agricultural engineering."

The lowest grade of membership is Junior for which the qualifications are: "Graduate in a professional agricultural engineering course from a school of accepted standing, or one who has equivalent attainments."

There is provision for student branches: "A student member shall be a student regularly enrolled and pursuing an approved agricultural engineering curriculum in a school of accepted standing."

ARCHITECTURAL ENGINEERING

Architectural engineering is a combination of architecture and structural engineering, or a specialized branch of architecture related to civil engineering. Usually, the function of the architect is to create the structure, including purpose, location, convenience, proportion, style, and factors of beauty. He is an artist whose design pleases the eye with a structure that serves a utilitarian purpose.

The structure must have more than beauty — it must have strength; it must be built economically; it must be useful. This

Architectural engineering students discuss a class project which deals with the materials and method of construction of a small modern building. This step follows the drawing of plans, as shown on the walls. Later, the architectural engineer may supervise the construction of this and similar buildings.

demands a wide range of technical skill. Generally, architects are not qualified to make the necessary analyses and to design the supporting structure and structural details. For this they call on civil engineers who have specialized in structures.

The architectural engineering curriculum has been established to prepare men to conceive, plan, and design the structure and its appurtenances. The graduate has received fundamental training in architectural design, structural design, building construction, mechanical equipment of buildings, and materials of construction, which qualify him to handle the complete design of the building and supervise its construction.

The design of modern steel and concrete office and industrial buildings, hotels, churches, public buildings, and monumental structures requires a careful study and a thorough understanding of the heavy loads which the foundations and framework must carry. In the early days before the era of steel construction, relatively little scientific or mathematical attention was given to the design of the foundation or the superstructure. In those days making a new design involved a comparison wih existing structures, plus experience and judgment. But the advent of steel construction changed all of that. Now there must be an analysis of all stresses caused by all loads, such as weight of structure, loads to be imposed, wind, vibration, and others. This analysis is preliminary to determination of the amount of steel or other structural materials (weight, size, and shape) that is required in roof trusses, columns, and floor members, to make the building safe.

In addition to being safe the building must also be economical, convenient, and attractive. Furthermore, the complex problems in connection with planning of the building services — heating, ventilation, lighting, and others must be understood by the architectural engineer so that he can make provision for those services. The details of their design would be handled by specialists in each of those fields.

Fields of Architectural Engineering

There are several major fields in which architectural engineers are engaged. These include:

Architecture. Some enter architects' offices where they work on the architectural or structural, or both, phases of design. Their experience is apt to include drafting and design, and inspection while acting as the architect's representative on the construction job. One of the significant aspects of the architect's practice is that he usually serves as a consultant, is the owner of his own business, and deals with his clients personally on the basis of a fee instead of a salary.

Construction. This broad field takes many architectural engineering graduates each year. They work for the contractor as timekeeper, checker, or instrumentman, for the owner as inspector, for the architect as inspector and, when experienced, as superintendent. Here is a field where practical or trade experience, such as work at carpentry, bricklaying, and the like, are very helpful to a young engineer who seeks a career in the construction field. He will be inspecting and checking the workmanship of skilled craftsmen. They will respect his judgment, and he can do a better job, if he has had some actual craft experience.

Engineering Sales and Service. Here, as in several engineering fields, there has been a growing need for engineers who can bring the results of technological improvements to the user and consumer. For example, millwork companies have engineers on the road who confer with and give technical advice and service to dealers and users of their products. Manufacturers of synthetic lumber, fixtures, sound proofing, acoustical boards, and other materials, offer a similar service. Frequently, this service includes the supervision of installation as well as the selling. These jobs offer many opportunities to combine engineering and business in a pleasant and profitable manner.

Structures. This includes the planning, design, and construction of buildings in steel, concrete, reinforced concrete, brick, timber, and other building materials. Generally, the architectural engineer confines his structural work to buildings, such as stores, apartment houses, hotels, theaters, and office buildings, leaving bridges, dams, and the like, to civil engineers. Work assignments include drafting, checking, calculating, estimating, inspecting, testing. Most of this is office work.

Industrial Design. This new field, which combines art, science, a sense of proportion, creative ability, imagination, and natural mechanical sense to an unusual degree, has grown up during the last decade. We shall list it under the architectural engineering fields although it would be fair to say that industrial designers are born, not made. The objective of industrial designing is to create a product which appeals to the senses, does not appear illogical, and will do its job. Probably the common word for this is "streamlining." It seems to offer a promising future for those who have the talent.

Characteristics of Architectural Engineers

The ideal architectural engineer would have a combination of aptitudes for the artistic and the scientific. He should (1) have an aptitude for creative design and a sense of harmony of color, form and design, and materials, part of which can be acquired through training and study; (2) enjoy and have some aptitude for freehand drawing and sketching with pen, pencil, and water color; (3) have an interest and some manual skill in drafting, both architectural and structural, because a large percentage of the architectural engineer's college work is on the drafting board; (4) be accurate and creative in the type of analysis and calculation that is used in structural problems.

Professional Organization for Architectural Engineers

The American Institute of Architects is the professional organization for many of the architectural engineers who engage in activities closely related to architecture. Its objectives as stated in the constitution are: "to organize and unite in fellowship the architects of the United States of America; to combine their efforts so as to promote the aesthetic, scientific, and practical efficiency of the profession; to advance education in architecture and in the arts and sciences allied therewith, and to make the profession of ever-increasing service to society."

Members are chosen from architects who have "the professional qualifications required by the board for admission to corporate membership, an honorable standing in the profession and in his community, and [the ability] to undertake the pecuniary obligations of membership."

Chapters of the institute may make provision for junior associates whose qualifications are: "Any architectural draftsman of good character and reputation living or employed in the territory of the chapter who is able to undertake the pecuniary obligations of a junior associateship and neither is engaged in the practice of architecture as a principal nor is legally licensed or registered so to do . . . An undergraduate or post-graduate student in a school of architecture recognized by the Institute . . . may be admitted . . . to junior associateship as a Student Associate."

CERAMIC ENGINEERING

Practice of the ceramic art is very old. The word *ceramic* came from the Greek word *keramos* which means burned stuff or burned clay. For centuries ceramics was an art and a field of the skilled workman who made objects with his hands. Developments in science and technology have brought many of their applications to the ceramic field. Out of this has evolved Ceramic Engineering which we may call the application of scientific principles to the fabrication of ceramic products; the mining, refining, and processing of raw materials; their manufacture into finished products; and the design, construction, and operation of the equipment required.

The field is not well known to the average citizen. Yet the value of its annual manufactures is large and there are many employment opportunities. The products include everything manufactured from earthy (nonmetallic) minerals. The actual work of the ceramic engineer may be described best by discussing the divisions, or fields, of the industry which are based, in the main, upon the nature of the finished products.

Fields of Ceramic Engineering

Structural Clay Products. This is the ceramic field best known to the general public because plants in which these products are made are surrounded by large open yards in which brick and tile are stored. Products include terra cotta, building brick, structural tile, quarry tile, drain tile, and sewer pipe. In the past this field has been dominated by the "practical" man who grew up with the business. Competition has brought the necessity for new processes and new products at lower costs. Here we find the ceramic engineer taking a hand in all phases of this field including the design and construction of plants, their operation, research, and selling of products.

Ceramic and chemical engineers must make many chemical tests to determine and control the nature, quantity, and quality of products. Here, ceramic engineers are doing fundamental research on clay minerals.

Refractories. Included here are fire clay, silica, chrome, and magnesite refractories, crucibles and muffles, glass pots and tanks, zinc and glass retorts, insulating bricks, refractory cements. This is an important section of the industry because most of the melting processes, such as those in the manufacture of iron and steel, depend upon a furnace lining that will stand up under intense heat. The word refractory means difficult to melt, fuse, or reduce.

Abrasives. As materials used in manufacturing processes are made harder we must develop harder grinding wheels to sharpen the tools that will shape the material. These sharpening devices and some cutting tools are made from silicon carbide and aluminous abrasives by the ceramic engineer.

Enameled Metal. This is used in sanitary enamelware, household ware, walls and partitions, stoves and refrigerators, signs, and many other things. It is a rapidly growing field. Good appearance, ease of cleaning, strength, and freedom from rust are some of the characteristics of enameled metals. The ceramic engineer who masters this field must have a thorough knowledge of the physical and chemical properties of metals and enamels.

Glass. This includes household glass, window glass, building glass and tile, bottles and containers, mirrors, quartz glass, tubing, glass textiles, reinforcement and insulation, electric light bulbs and vacuum tubes, and many others. One of the interesting things in this field has been the development of glass products that have some of the properties of metals, such as pliability with strength.

Whiteware. Included here are tableware, kitchenware, art pottery, sanitary ware, stoneware, chemical porcelain, electrical porcelain, floor and wall tile. At this point the engineer meets the artist whose help he must have in the design of artistic shapes and patterns.

Cements, Limes, and Plasters. This includes portland cement, gypsum products, magnesia and zinc cements, dental cements, plasters, and others. Some of these are in borderline industries where chemists, chemical engineers, and ceramic engineers have interests and claims.

A brief consideration of these fields will make one fact very clear; namely, a thorough knowledge of chemistry and physics is required of the ceramic engineer. This is true regardless of the type of work that he may do in any industry, including research, design, development, operation, or sales.

Characteristics of Ceramic Engineers

The young man who is considering ceramic engineering should have these special characteristics: (1) a positive and better-than-average liking and aptitude for chemistry and physics, because these two subjects, separately and in combination, are the basis for much ceramic engineering theory; (2) an interest in making things and an aptitude for handling tools and instruments; (3) good health and good physique, because some of the early work may be hard, and because of high temperatures and dust at some plants; (4) a definite predisposition for hard and sustained work, some of it manual, and no objection to getting his hands dirty. This is for the reason that there is a variety of plant equipment which the ceramic engineer must maintain and operate.

Professional Organization for Ceramic Engineers

The professional organization for ceramic engineers is the American Ceramics Society. Inasmuch as this is a society for the artist and craftsman as well as the engineer, the entrance requirements do not have the rigorous technical slant of some of the other engineering societies.

The object of the society as stated in its constitution is "to advance the ceramic arts and sciences by meetings for the reading and discussion of papers and publications of scientific literature, and other activities."

Associate members must be persons interested in ceramic or allied industries. Active members must be persons competent to fill responsible positions in ceramics. There are provisions for the establishment of student branches.

CHEMICAL ENGINEERING

Chemical engineering as a distinct profession is so new that the men who created the first college curriculums are still living. By definition we would say that "the chemical engineer is one who is skilled in design, construction, and operation of industrial plants in which matter undergoes a change,"[1] or, "one able to conceive improvements and inventions in terms of chemistry and competent to reduce them to actuality in terms of engineering science."[2] An important part of the chemical engineer's work is to manufacture products using controlled physical and chemical changes on a large (plant size) scale. Some of these changes are made by altering the physical state of the basic raw material; other changes are made through chemical reactions.

The growth of the chemical industry, both in size and the multiplicity of products, has been one of the most amazing developments of this quarter century. There is scarcely an article of our daily life — food, clothing, shelter, medicines — that has not felt the touch of the chemical engineer. These accomplishments have intrigued our imaginations to the point where we are expecting all sorts of developments. The reclamation and use of sewage wastes; the commercial utilization of waste farm products such as cornstalks and straw; the manufacture of synthetic foods; the use of synthetic products to replace metals for small and large objects, including those that must carry substantial loads and resist bending stresses; these are examples of things that are here, and others will follow.

As with many other professions, we find that there was a sort of art of carrying on chemical manufacturing before the discovery of the scientific principles upon which the art was based. At first the practitioners were industrial chemists — men who used chemistry and some practical mechanical engineering. As the industry grew in size and complexity it became evident that a large number of operations were duplicated in many industries. Out of this observation grew the "unit operation," which is the basis of chemical engineering.

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[1] *Chemical Engineering Plant Design,* Vilbrandt, McGraw-Hill Book Co., 1934, p. 1.

[2] *Vocational Guidance in Engineering Lines,* Amer. Assn. of Engineers, 1933, p. 93.

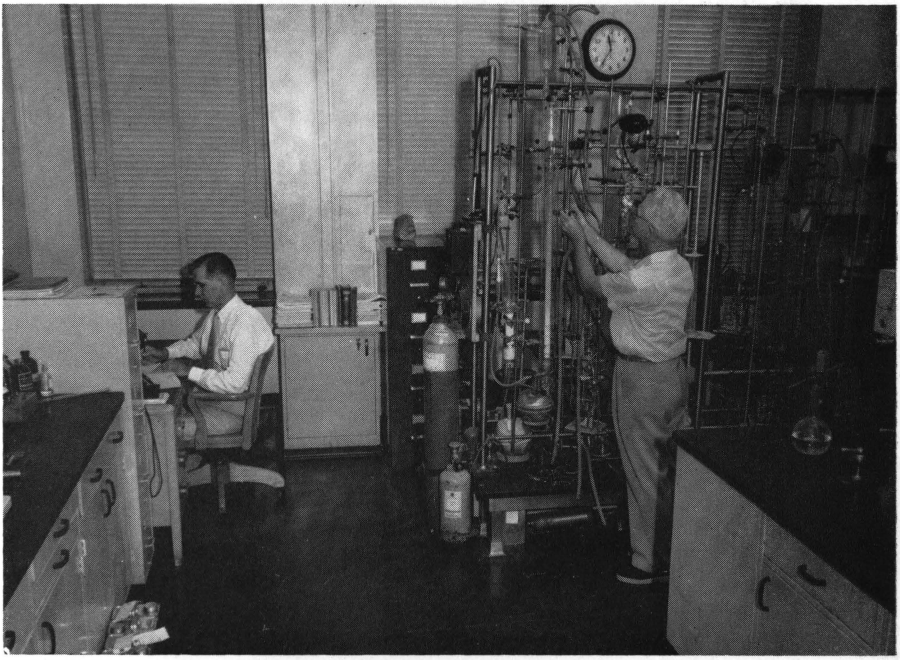
Some unit operations are: mixing, crushing, grinding, size separation, crystallization, filtration, distillation, drying, and many others of a highly complicated nature. Their development has simplified the treatment of chemical engineering because a large list of independent manufacturing processes was replaced by a smaller list of unit operations. Furthermore, specialization in one or more of the unit processes would not limit a man to a particular industry, because each of these unit operations, although carried out in a wide range of types of equipment, is solved by the application of a few fundamental laws. Each manufacturing process, then, consists of an integrated group of these unit operations.

Chemical engineering enterprises lend themselves to the ideal development from the conception through the successive steps of laboratory stage, small-sized model, large-sized or development unit, semicommercial plant, and finally, commercial plant. This sequence or evolution of steps should assure a technically and commercially sound development.

Fields of Chemical Engineering

From the foregoing discussion it can be seen that chemical engineering does not split into major branches as do some of the

Before chemical manufacturing processes can be used on a full-size plant scale, they must have tests in small scale operations in a pilot plant. These chemical engineers are carrying on a pilot plant study. (Courtesy Esso Standard Oil Co.)



other engineering departments. To list special fields we shall turn to the separate industries which include: organic chemicals; heavy chemicals; iron, steel, and coke; meat packing; food products, soap, and glycerine; petroleum products; textiles; nonferous metals; chemical equipment.

Products include acids, alkalies, salts, coal-tar products, dyes, plastics, insecticides, drugs, cosmetics, explosives, fertilizers, leather products, oils and fats, paints, paper, petroleum products, synthetic fibers, rubber products, soaps, chemicals from coke-oven products.

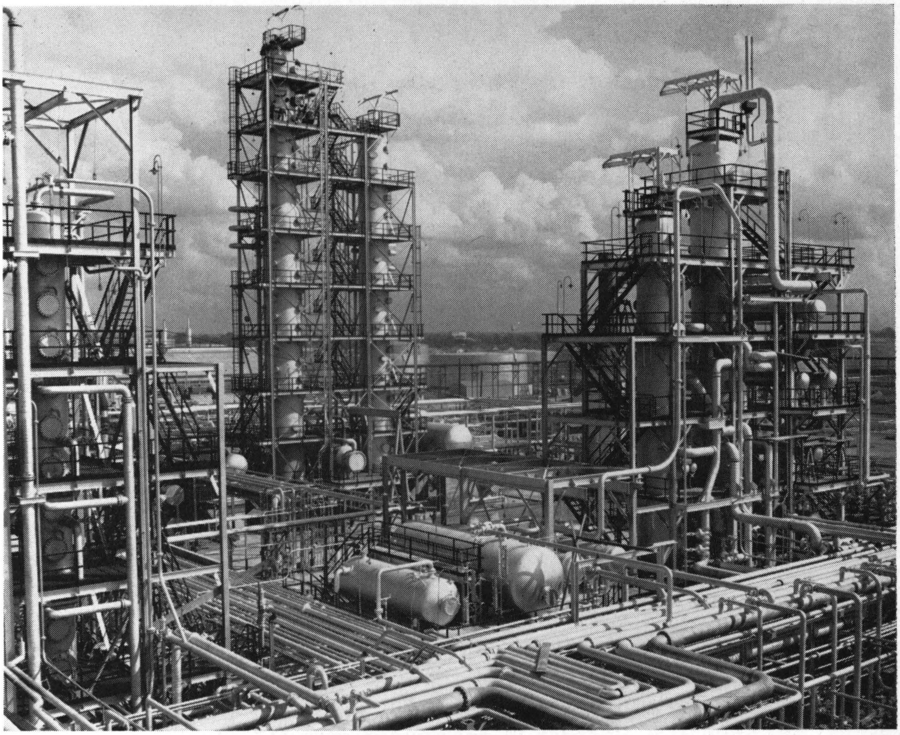
The chemical engineer's work can best be described below by listing some of the functional operations of the industry.

Process Control and Instrumentation. The duties include: (1) tests on qualities of raw material to make sure that they comply with specifications, and to furnish data on their varying composition so that batch proportions may be changed accordingly; (2) tests during the manufacturing process, including temperature, pressure, color, rate of mixing, and others, plus numerous laboratory tests and analyses of samples; (3) tests of the finished product.

Production. Engineers operate and adjust equipment so that it will perform chemical operations efficiently and uniformly, yielding maximum production at minimum cost. During his training period the young chemical engineer will be required to perform many of the manual operations of production. Later, when he has shown that he is prepared for the responsibility, he will be placed in charge of a group of workmen. From that time his progress will depend upon his success in planning and directing the work of others, and in his understanding of the operations, rather than upon any particular manual ability. This line leads to the position of plant superintendent and works manager.

Development. Development in chemical engineering has several stages, beginning with the laboratory stage and ending when the process is ready for utilization on a commercial plant scale. Intermediate steps are the pilot and semiworks plant. Here the problems of application of materials of construction, reaction speeds, time, temperature, mechanical details of operation, and others, go through progressive refinement in preparation for the large-scale operation. The young engineer has a splendid opportunity here to learn the details of manufacturing processes. There are required thorough knowledge of fundamental operations and ingenuity in seeing where and how improvements may be made.

Design. This may follow or accompany development. It involves the adaptation of the experimental or semiworks plant to commercial operation. This refers both to the processes and the equip-



With this maze of pipes and towers the chemical engineer converts refinery gases into useful petroleum products. (Courtesy Standard Oil Co., Baton Rouge, Louisiana.)

ment. It will require work on the drafting board and time in the plant checking performances of the equipment.

Research. Research in chemistry and chemical engineering is very important. Millions of dollars are spent by large companies to discover new products and improve old ones. Huge staffs are employed on this work, which ranges from routinized analyses to the most complex scientific problems. Many men of many abilities are employed.

Sales. Sales covers materials, products, and equipment.

Characteristics of Chemical Engineers

Special traits of the chemical engineer should include: (1) a distinct aptitude for and a real and continuous interest in chemistry; (2) no objection to the characteristic odors, fumes, or high temperatures that prevail, frequently, in chemical plants; (3) good health with no predisposition to pulmonary diseases; (4) keen power of observation and strong inclination to be careful in his work around the plant, because the forces with which he works are out of sight in huge pieces of equipment; (5) an interest in processes of manufacture where the essential operations are carried on unseen in closed containers, in contrast with mechanical manufacturing processes where most of the steps may be observed. It is essential that he be interested in manufacturing, that is, the applications of chemistry to industrial enterprises on a commercial scale. Therein lies the difference between a chemist and a chemical engineer. The interest and training of the former usually does not go beyond the laboratory where new ideas and processes are conceived and tested. The chemical engineer carries on from this point.

Professional Organization for Chemical Engineers

The professional society for chemical engineers is the American Institute of Chemical Engineers. Its objectives, as outlined in the constitution, are: "The advancement of Chemical Engineering in theory and practice and the maintenance of a high professional standing among its members."

The beginning grade of corporate member is Junior Member. Candidates must be more than 21 and not more than 30 years of age. They must have specified amounts and types of experience, or have B.S. degrees in recognized curriculums. The institute has established student chapters in several engineering colleges. Students are entitled to certain privileges and to receive bulletins and other notices of the institute.

CIVIL ENGINEERING

Civil engineering consists of the economic application of the laws, forces, and materials of nature to the design, construction, maintenance, and operation of works and structures; also the research, testing, sales, management, and other related functions. The works and structures include such things as transportation; bridges and buildings; water supply, sewerage, irrigation and drainage systems; river and harbor improvements; dams and reservoirs; surveys and maps.

The civil engineer is a servant of the public, a public service engineer. He plans, designs, and builds the water and sewerage systems that safeguard our health; he plans and builds transportation systems that carry us safely, smoothly, and swiftly, and that bring us food and materials from all parts of the world; he helps in the design and construction of the buildings in which we live and do our daily work; he provides the engineers of industry with orderly, well-planned, correctly designed, and well-constructed facilities with which they produce innumerable manufactures.

In this research project the civil engineer is testing a prestressed concrete bridge beam in a testing machine capable of applying a load of 400,000 pounds. The electrical equipment in the foreground is being used to measure the effects of loads applied with the testing machine.

He helps to make things, such as bridges, roads, dams, and tunnels, that are specific and individual units, each requiring study, special plans, and unique construction arrangements. For example, Boulder Dam could not be built at Fort Peck; the water supply system of New York could not be copied for Chicago. Therein lies a significant difference between the works of the civil engineer and those of his brother engineers in industry. They help to make machines and goods in large quantities for early consumption. Moreover, the factory that manufactures these products must have constant supervision by engineers to maintain a standard quality. The bridge or the dam built by the civil engineer will serve satisfactorily for many years without any attention other than routine maintenance and replacements.

However, highways, bridges, buildings, and all types of public works wear out or become inadequate for modern use. Devastating floods and windstorms destroy in a few hours many lives and billions of dollars' worth of public and private property. Population is growing and there is corresponding expansion and improvement of old areas and development of new areas. All of this calls for an increasing number of better-prepared civil engineers to do the new work and to improve and maintain the old.

Fields of Civil Engineering

We may classify work of the civil engineers according to field or function. Using the list of technical divisions of the American Society of Civil Engineers we find the following fields and functions in which civil engineers specialize: City Planning, Construction, Engineering-Economics and Finance, Highway, Irrigation, Power, Sanitary Engineering, Soil Mechanics, Structural, Surveying and Mapping, Waterways.

Courses of the junior and senior (and graduate) years of civil engineering curriculums are based upon several of these fields. In many colleges advanced courses are offered as options in the senior year. We shall consider these briefly.

Surveying includes mapping, geodesy, and aerial surveying or photogrammetry. All civil engineers receive considerable training in surveying and map making, and many begin their work after graduation on the surveys which are the beginning of most engineering projects. A number have made careers in the fields of surveying and mapping, principally with the federal, state, or local agencies.

Highways and Railways have related problems, so they are combined frequently under *Transportation.* This work includes the planning, location, design, construction, and maintenance of roadbeds, bridges, culverts, tunnels, and grade separations. Work with railways is largely private employment, while that with highways is largely public.

Everyone who drives an automobile knows that we need better — wider, smoother, stronger, safer — highways. While toll roads attract attention, and they are important, the big job of the civil engineer in Transportation is in the daily search for new materials, new methods, new and better ways of using all materials. The need for civil engineers to do these things is very great and the supply too small.

Hydraulics deals with the planning, design, and construction of dams, reservoirs, and systems of conduits or canals for impounding and distributing water for municipal supplies; the reclamation of swamplands and the control of rivers; the planning, design, and construction of water power and irrigation projects; river and harbor improvements, and many others.

Sanitary and Water Supply deal with the removal, treatment, and disposal of wastes from households and factories, and of storm water from cities and towns; the collection, treatment, and distribution of public water supplies. The problems of public water supply and waste disposal are very closely related, so we find these two branches combined frequently in the engineering curriculum and in the city administration. There is a growing realization of the great importance of these two subjects and the related field of preventive medicine, so there has evolved a new name, sometimes designated Public Health Engineering.

Structures enter more or less into the work of all branches of civil engineering. Specifically, this branch has come to mean the special technique required for the design and construction in steel and concrete of many bridges, modern industrial buildings, and skyscrapers. Because of the necessity for economy of design and construction, and for the safety of the completed structures, such work can be entrusted only to skillful specialists.

Characteristics of Civil Engineers

The typical civil engineer should choose this field with the following points in mind: (1) A career in civil engineering still offers an opportunity for outdoor work with variety of activity and environment. In the past this meant a roving existence and a type of life that appealed to many young men. Those opportunities for travel and nomadic living are not so numerous as they were fifty years ago when every civil engineer got his start in a camp. Enough such assignments are available to satisfy those who choose the out-of-doors life. On the other hand, there are equally interesting jobs for men who prefer to remain indoors. (2) To an increasing extent the engineering on public works of all types is becoming a function of some governmental agency. This means that a large percentage of civil engineers, probably more than 50 per cent, may except to become employees of some unit of government — federal, state, county, city. (3) Because civil engineers do have many contacts with the public, they should have personalities that help to make those relations pleasant. (4) A typical civil engineer does not enjoy manufacturing and its mass production methods. (5) He prefers to deal with static (resistance to motion) forces rather than with the dynamic forces of moving parts.

Professional Organization for Civil Engineers

The American Society of Civil Engineers is the professional organization for civil engineers. Its objectives, as stated in the constitution, "shall be the advancement of the science of engineering and architecture in their several branches, the professional improvement of its members, the encouragement of intercourse between men of practical science, and the establishment of a central point of reference and union for its members."

Members are chosen from the ranks of civil, military, naval, mining, mechanical, electrical, or other professional engineers, architects, or marine engineers. The lowest corporate grade is Junior Member for which the requirements, as stated in the constitution, are active practice in some branch of engineering for at least four years, or graduation from a school of recognized standing; at least twenty years old.

The society has established student chapters in the majority of the schools of engineering in the United States. In addition to numerous technical and professional privileges and contacts, student membership entitles an applicant to a reduction in fees when he applies for corporate membership after graduation.

ELECTRICAL ENGINEERING

Electrical engineering is young both as a science and as a practice or art. The first practical application of electricity and magnetism came in the early telegraph systems which followed Morse's discoveries, shortly before 1840. This was followed by Bell's telephone in 1876 and Edison's development of the electric generator and the incandescent lamp in the early 1900's. The World's Fair at Chicago in 1893 really opened people's eyes to the electrical progress that had been made and gave a hint of what might be ahead. Since that time the results of the discoveries and inventions in the realm of electricity have had a marked influence on the lives and habits of people in all parts of the civilized world. It is not exaggerating to say that without these inventions modern industrial achievements would have been impossible. Everywhere we see astonishing applications of recent electrical developments. The photoelectric cell in countless uses, television with commercial usage, the X-ray in industry, electric welding replacing riveting, transmission of pictures by wire, radar, and numerous automatic controls — these are a few of those developments.

Fields of Electrical Engineering

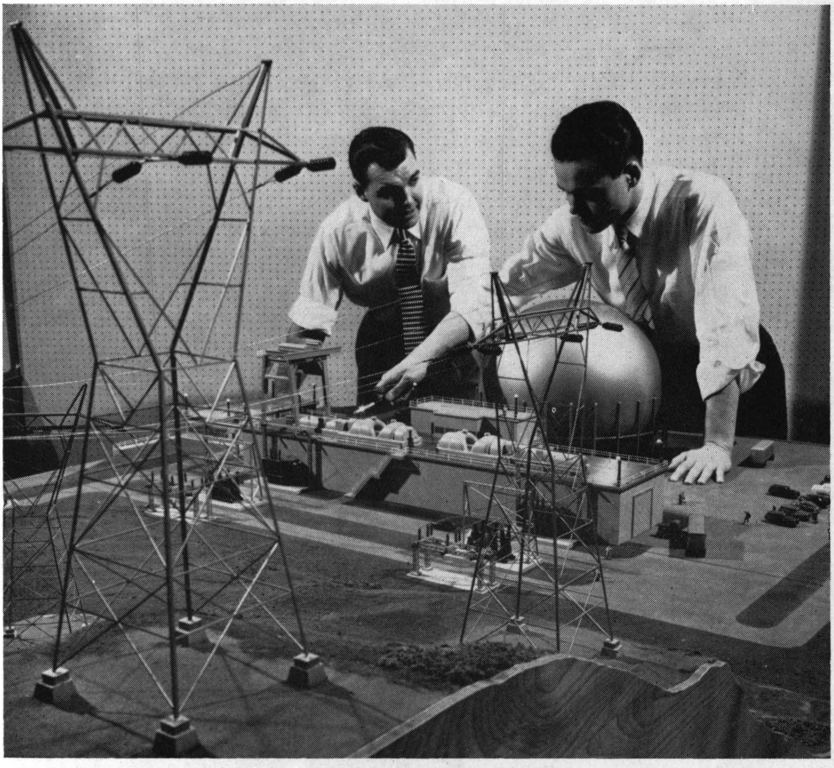
There are several fields of specialization in electrical engineering, each requiring a high degree of specific knowledge. The American Institute of Electrical Engineers has the following technical committees: Automatic Stations, Communications, Education, Electrical Machinery, Electrical Welding, Electrochemistry and Electrometallurgy, Electrophysics, Instruments and Measurements, Applications to Iron and Steel Production, Production and Applications to Marine Work, Applications to Mining Work, General Power Applications, Power Generation, Power Transmission and Distribution, Protective Devices, Research, Transportation.

The electrical industry and electrical engineering may be divided, for convenience, into two main fields. One includes the applications of electricity to light and power where large values of current at low or high voltages are used for such equipment as power generators, motors, and welding apparatus. The other covers the application of electricity to its uses in communication where there are minute currents at minute voltages such as are used in telephone, telegraph, radio, and electronic equipment.

Subdivisions within these two broad fields of power and communication have been designated by specialty names, and several are recognized as options for seniors in the curriculums of many electrical engineering departments.

Illumination includes the conversion of electrical energy into light, the designing and manufacture of light sources and reflecting media, and the planning and installation of lighting systems. Tremendous progress has been made in this field. People expect better lighting in homes, factories, streets, and, most recently, on the highways. In addition to these utilitarian uses, electricity is

Two electrical engineers observe a model of the plant and apparatus that are required for the generation and distribution of electricity. This includes power plant, generators, transformers, transmission towers, and lines. (Courtesy General Electric Co.)



used very effectively in many beautiful and spectacular displays in show windows, public buildings, and exhibitions.

Communication covers telephone, telegraph, and radio, including television, wire and wireless transmission of pictures, wireless-telephone communication with ships and airplanes, and others. It would be fair to say that this field typifies electrical engineering in the popular mind.

Electronics is the practical use of the flow of electrons through space. The principle has many applications, such as taking measurements, inspection and sorting of parts and materials, welding control, motor-speed control, voltage regulation, induction heating, dehydration of food, rectification and inversion from a-c to d-c power, guided pilotless airplanes and guided missiles, and others.

Transportation covers the uses of electricity for vehicles, wires, and track that are used to carry people in trolley buses, trolley cars on tracks (rapidly disappearing), and railroad trains. As our cities grow, the rapid and convenient movement of people by public transit becomes an increasingly important matter. On the railroads the electrification of sections, particularly those adjacent to large cities, has continued. Recent advances in the use of diesel-electric and steam-electric motive power have brought new electrical problems. Automatic train control is another electrical engineering problem in this field.

Power (generation, transmission, distribution) becomes more important each day as the federal government pushes its program to bring cheap electricity to everyone who would use it. The slogan seems to be "bigger and better" — bigger generating units, higher voltages, larger networks for transmission, longer transmission distances, all of which bring new and challenging problems for electrical engineers.

Manufacturing includes every type of electrical equipment from the heavy machinery used in power plants and in transportation to the very delicate devices used in telephones and radios. There is a tendency everywhere to replace mechanical with electrical power. This introduces problems in design and manufacturing that must be shared by electrical, industrial, mechanical, and other engineers.

Characteristics of Electrical Engineers

Qualifying or distinguishing characteristics of an electrical engineer are: (1) mathematical aptitude above that of engineers in other departments, particularly in the quality of abstract reasoning; (2) a liking for physics; (3) a leaning toward the theoretical and

This electrical engineer is receiving data on tests of radar height-finder. Radar's energy is concentrated in a narrow beam like that of a searchlight and is powerful enough to light fluorescent lamps one hundred feet away. (Courtesy General Electric Co.)

scientific rather than the practical; (4) less interest in the manufacturing operations than in the developmental steps leading up to manufacturing, as indicated by (3). Speaking somewhat figuratively, we may say that most of the problems in electricity are invisible, because electricity is energy without material body, so these problems must be treated and understood through their expressions in the form of symbols. The solution of many of these problems requires the most exacting mathematical analysis.

Professional Organization for Electrical Engineers

The American Institute of Electrical Engineers is the professional organization for electrical engineers. Its objectives as stated in the constitution "shall be the advancement of the theory and practice of Electrical Engineering and of the allied arts and sciences and the maintenance of a high professional standing among its members."

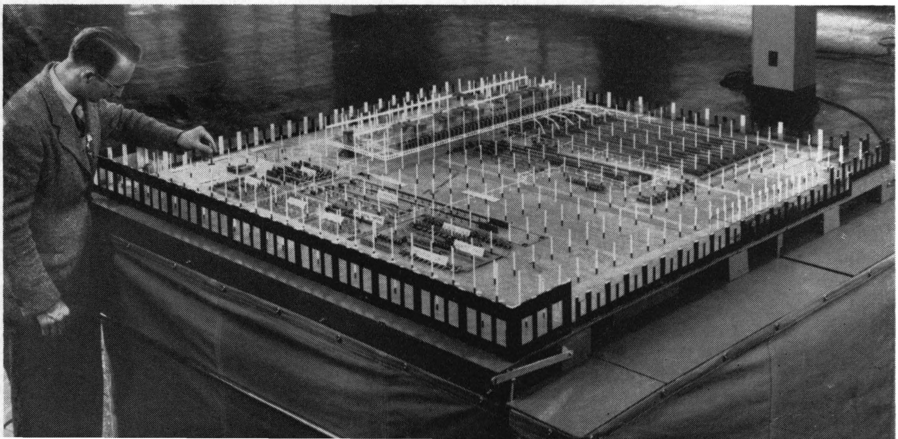
The lowest grade of corporate membership is Associate Member. The requirements are: not less than twenty-one years of age; a graduate of an approved engineering curriclum, or equivalent attainments, including five years of increasingly important engineering experience indicative of growth in engineering competence and achievement: either an electrical engineer by profession or a teacher of electrical engineering subjects. There is also a grade of Student Member. The institute has established student branches in many of the engineering colleges of the United States.

INDUSTRIAL ENGINEERING

Industrial engineering is a relatively new professional field, whose development has paralleled the growth of the machine age. It may be defined as the branch of engineering which plans for the actual manufacturing of the products of industry. It also includes design of the machines and the selection of the machines that are to be used in the manufacturing operations. The slogan of the industrial engineer might be: Obtain the best economy in the use of men, machines, materials, and money. He is the man with the "know-how" who can bring men and machines and materials together, use the machines and materials most efficiently, and give the men the most benefits for their contribution to production.

In the industrial engineering curriculum advanced technical courses, particularly in the area of design, are replaced by a group of courses that deal with the management of materials, men, and money. These include such courses as Safety Engineering, Engineering Economy, Personnel Supervision, Job Evaluation, Time and Motion Study, General Accounting.

This is a cutaway scale model of a proposed manufacturing plant. The industrial engineer is arranging models of machines and equipment to give the most effective production when the plant is built. (Courtesy Western Electric Co.)



Fields of Industrial Engineering

There are several fields that might be listed as areas of specialization for the industrial engineer. These are time and motion study, methods study, cost control, quality control, production planning.

Time and Motion Study. The industrial engineer employed in time and motion study observes the operations of men and machines with or without the aid of motion pictures. He uses this information as an aid in establishing incentive wages, to improve the scheduling (order in which work is done), and to obtain information about costs.

Methods Study. The engineer engaged in methods study may use some of the time and motion study techniques, but his emphasis and major study are on the machines. He makes constant studies to develop better methods for handling materials.

Cost Control is an effective tool of factory management. It seeks to eliminate waste and unnecessary usage of materials and labor, and to obtain maximum production through the analysis and effective coordination of the various activities of the company. The cost control operation is applied to equipment repairs and maintenance as well as to production line operations.

Quality Control calls for continuous checks of the production procedures to make sure that qualities such as weight, thickness, color, taste, hardness, strength, and durability meet the specifications. This calls for the use of modern devices such as spectrographic and X-ray equipment, electronic machines, optical tools, and various pieces of apparatus for making chemical analyses.

Production Planning. The industrial engineer who engages in production planning needs a thorough knowledge of his plant's capacity to do work. He must make sure that the raw and partly finished materials are in the right place, in proper amounts, at the right time. Also, he must have the right machines, in proper sequence, in sufficient quantity, with enough power to operate them. Similarly, there must be enough men, with the required skills, to operate the machines.

Characteristics of Industrial Engineers

Qualifying or distinguishing characteristics of an industrial engineer are that he should (1) enjoy working with people and have a knack for directing them, (2) have the ability to visualize, that will enable him to select machines and plan their use, (3) have the ability to express himself clearly both in the written and spoken form, (4) have many of the qualities of a successful salesman.

Professional Organization for Industrial Engineers

The American Institute of Industrial Engineers is the professional organization for industrial engineers. It is one of the newest members of Engineers Joint Council and is represented on all EJC Committees. Its organization is similar to that of the founder societies. Its monthly publication is the Journal of Industrial Engineering.

The lowest corporate grade of membership is Associate Member for which the requirements are: B.S. in Industrial Engineering and three years of engineering experience.

The institute has established student chapters in ECPD accredited schools.

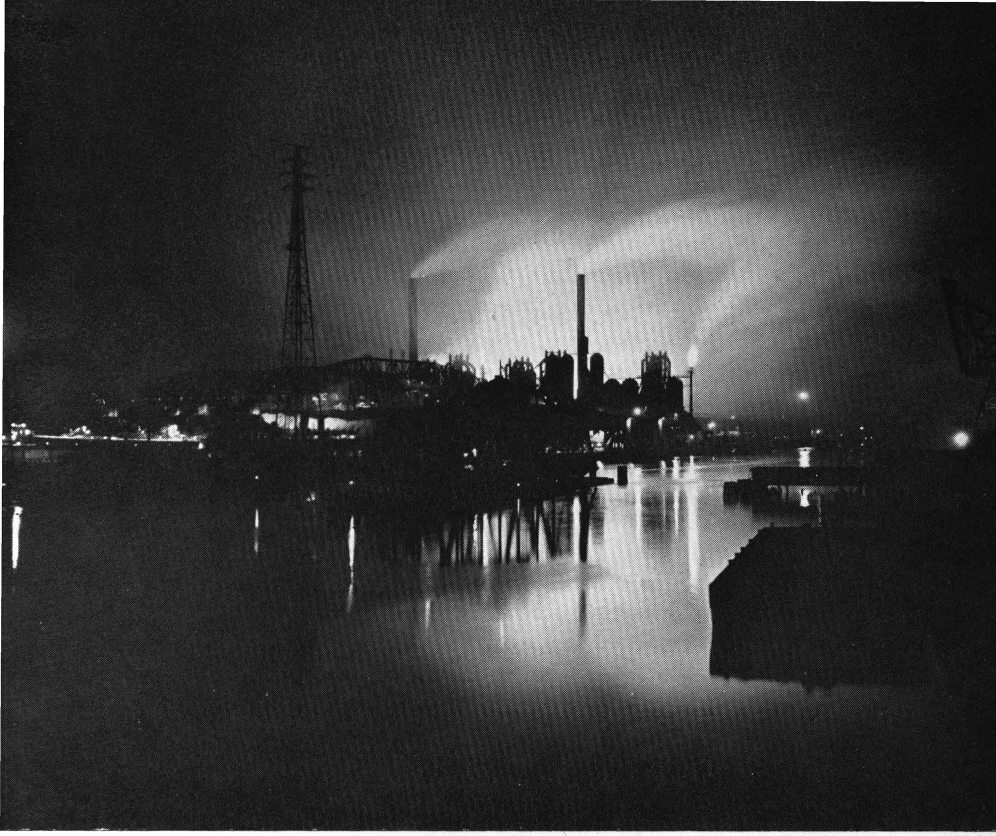
MECHANICAL ENGINEERING

Mechanical engineering underlies every type of engineering where a manufactured product is involved. Furthermore, its operations are basic in transforming energy from its simple state, such as coal or oil, into usable energy. In its strictest sense it relates to the engineering of machines. Actually it includes all industrial activities from extremely fine watchmaking and instrument design to such large operations as locomotive-building and the design and operation of power plants.

Although these machines and devices are new, the principles upon which they operate are very old. The energy from a running stream of water was applied to the grinding of corn long before the Christian Era. The elements of the atmospheric engine were included in an ingenious device for opening temple doors. This was described by Hero of Alexandria about 200 B.C., but the atmospheric engine was not devised until 1712 by the Marquis of Worcester. James Watt developed this into a steam engine about 1774. This same Hero described a piece of apparatus resembling a reaction wheel, but there was no successful reaction turbine until Parsons built one in 1884.

There are similar examples in other branches of mechanical engineering, all showing how recent our industrial development is. The first internal combustion engine was built in 1675 and used gunpowder as a fuel. Mechanical refrigeration had practical application in 1755, in the construction of a vacuum machine which facilitated the freezing of water by evaporation.

The most recent and startling developments are atomic power and the jet engine. Both will have significant industrial applications to peace-time uses, although their military uses are best known now.



This night picture of a steel mill epitomizes manufacturing, which is the work of the mechanical engineer. Power is produced from the gas that comes from the huge blast furnaces, where mixtures of coke, slag, and iron ore are turned into molten metal. Power is used to operate the huge machines that shape this molten metal.

Fields and Occupations of Mechanical Engineers

The American Society of Mechanical Engineers has a number of technical divisions. These are: Aeronautics, Applied Mechanics, Fuels, Graphic Arts, Hydraulics, Iron and Steel, Machine Shop Practice, Management, Materials Handling, Oil and Gas Power, Petroleum, Power, Process Industries, Railroad, Textile, Wood Industries.

Mechanical engineering, as with many of the major professional areas of engineering, has several fields of specialization. Among these are: aircraft; automotive; heat-power; heating, ventilating, air conditioning; industrial; metallurgy; machine design. Many engineering schools offer optional courses in these special fields to seniors and graduate students.

Aircraft includes the research, development, design, and manufacture of power plants and accessories for all types of flying machines. The engine is changing from one that is rotating and internal combustion to a gas turbine, jet-propelled type. Temperatures are very high in the combustion chambers of these newer type engines and there are many difficult metallurgical problems.

Automotive, as we will consider it here, covers the research, development, and design of power plants for various types of self-propelled vehicles. This would include automobiles and trucks, diesel-electric locomotives, tractors and power machinery. Generally, this category has meant engines of the internal-combustion type, and has not included steam engines. This is a very large field that touches almost every aspect of our lives. Engineers who succeed in it need a good deal of ability, courage, and resourcefulness.

Heat-Power deals with the production of power from coal, oil, or gas (usually). Engineers in this field design, install, and operate boilers, turbines, coal and ash handling equipment, feed water purifiers, condensers, and all sorts of gauges and regulating devices. The steam engine is still a very useful and important source of power, particularly in large stationary plants where steam is used to run electric generators or to furnish heat for buildings.

Heating, Ventilation, Air Conditioning includes the design and manufacture, sale, installation, and service of equipment in homes, industrial and commercial buildings, offices, warehouses, and transportation units. It is a rapidly expanding field that is receiving much attention and advertising. The reader should remember that we are considering the work which an *engineer* does in this field. Many people have unwittingly confused the work of the engineer with that of the mechanic who installs, repairs, and services the equipment. The latter is a very important and necessary man, but he is not an engineer. It is the job of the engineer to design and direct the manufacturing of the equipment so that it will operate when correctly installed by the mechanic.

Industrial covers factory planning and layout, industrial relations, safety, production operations, the management of men, money, and materials. In some engineering colleges it is established as a curriculum. Because of the wide range of abilities needed in this field, a man who is not an engineer may do many phases of the work successfully.

Metallurgy requires a good knowledge of the chemical and physical properties of metals. There is a constant search for new metals, new alloys, or new ways of treating old metals to provide new and needed characteristics. The design of many products is limited by the strength and endurance of the metals that are available for their construction. Some metallurgists are working with metals to provide higher strengths; some are studying brazing and coating methods; others are specializing in welding processes and techniques. Metallurgy is an ever-widening field that calls for men trained in several specialized areas, including mechanical engineering.

Machine Design. Although this is a function and not a field, it represents a very important activity of mechanical engineers and merits special mention here. It covers all kinds of machines from prime movers, such as engines and turbines, to mill machinery, presses, lathes, milling machines, and other machine shop equipment. It ranges from the smallest part of a meter or gauge to the powerful machines that are used for forging or pressing metal. Successful designers of machines need keen analytical and creative ability.

As pointed out earlier, we may have artisans and craftsmen (mechanics), technicians, and engineers working in a factory or office on the same process or product. It may be difficult, in a specific case, to say which acts, manual or mental, are "engineering" and which are not. Each person contributes a necessary and important part. A young man should try to find an operation that fits his aptitudes and interests. It is a mistake and a waste of energy for anyone to try to do things that he is not equipped or prepared to do. There are tremendous opportunities in the various fields of mechanical engineering for many men who are not engineers, and the need for engineers is great.

Characteristics of Mechanical Engineers

The following traits are typical of the mechanical engineer. He should have (1) a liking for machines, mechanical equipment, anything that has "wheels going around." While he need not have above-average skill in the use of his hands — although that would be useful — he should really enjoy the noise and smell of machines and the feeling of grease on his hands. It is important for him to have (2) a better-than-average mechanical aptitude — that is, the ability to visualize objects in various space positions. He should have (3) a leaning toward the practical rather than the theoretical aspects of engineering, with an interest in "making something." His must be (4) a type of mind that thinks about material things, objects, rather than about the abstract.

Professional Organization for Mechanical Engineers

The American Society of Mechanical Engineers is the professional society for mechanical engineers. Its constitution states that its objectives are "to promote the art and science of Mechanical Engineering and allied arts and sciences to encourage original research; to foster engineering; to promote the intercourse of engineers among themselves and with allied technologists; and severally and in cooperation with other engineering and technical societies for broadening the usefulness of the engineering profession."

The beginning grade of corporate membership is Junior Member for which the requirements are: sufficient engineering experience to enable the candidate to fill a subordinate position in engineering work or a graduate of an engineering school of accepted standing; twenty-one years of age.

The society has established student branches in most of the engineering colleges of the United States. These student members are regarded as student associates of the American Society of Mechanical Engineers. They have opportunity to cooperate in many of the society's activities.

MINING AND METALLURGICAL ENGINEERING

Mining and metallurgy are associated in the name of their founder society. They are closely related in actual field operations, particularly in the mining of metals, but they differ in the manipulations. Generally, there are separate curriculums for mining and metallurgical engineering.

Fields and Occupations of Mining Engineers

The mining engineer extracts minerals from the earth and prepares them for the market. These minerals are commonly divided into three general groups: (1) metallic minerals, from which are extracted such metals as copper, iron, lead, zinc, gold, silver, and recently, uranium and thorium; (2) nonmetallic minerals, such as fluorspar, limestone, asbestos, sand, gravel, crushed stone, and clay; (3) fuels, such as coal, petroleum, and natural gas.

Exploration. The mining engineer requires a wide range of education because his work involves phases of several other kinds of engineering, such as civil, electrical, and mechanical, plus the science of geology. He must have a knowledge of the latter to enable him to locate ore-bearing strata, petroleum deposits, coal deposits, and other minerals. And he must be prepared to use intricate detector and measuring instruments. Recent advances in the

The mining engineer directs the field work of exploring and sampling a new prospect. Here he is shown mapping the surface geology exposed in the trench. He may stay to construct and operate the mine, or he may move on to a new field.

art and science of prospecting, in which sound waves are used, have taken some of the guesswork out of his job.

Surveying and Mapping. In a large mine the mining engineer would have the help of specialists in other fields — the civil, electrical, and mechanical engineer, and the chemist. But in a small mine he will have to do the work himself. This calls for property line and site surveys and the making of topographic maps. He may have to run surveys to map outcrops where the ore appears at the ground surface, and to locate boundaries of mining claims, or to map underground excavations. He may have to lay railroad track underground, and design and build structures at the mine site, including the power plant, smelters, and washers.

Mine Appraisal means determining the value of mine property and mineral desposits. This is also a duty of the mining engineer.

Assaying is the name for the quantitative analytical process used by the mining engineer in determining the percentage of metal in an ore.

Smelting. After the ore has been removed from the earth, it must undergo processing, usually smelting, to extract the metal which is usually mixed with materials that oftentimes have no use. Sometimes this smelting operation may be done at another site, as is the case with the ore that is mined in northern Minnesota and smelted at Gary, Indiana.

Exhaustion of the higher grade iron ore in the conveniently accessible ranges of northern Minnesota is the principal reason for a new development in the processing of iron ore. Lower grade ores are handled by a special process that removes some of the non-iron-bearing portion. The resulting product has an iron content high enough to warrant shipping to the smelters. This operation is in the field of the mining engineer.

Characteristics of Mining Engineers

The typical mining engineer should have: (1) above-average liking for outdoor work and for some fairly rough living conditions; (2) good health and physical endurance; (3) enjoyment of, and ability in, chemistry and physics; (4) considerable mechanical aptitude and ingenuity that will enable him to make emergency repairs and keep the machinery and plant in operation.

Fields and Occupations of Metallurgical Engineers

The metallurgical engineer takes up where the mining engineer leaves off. Metallurgy is the science that deals with the structure of metals and their alloys, their physical properties, and their thermal and mechanical treatment. A metallurgical engineer must have a good knowledge of physical chemistry. Recent developments in nuclear fission will have profound effects on the study of metal structure.

The mining engineer turns over the material to the metallurgical engineer at the smelter. Here the latter, sometimes designated an Extractive Metallurgist, begins the process of separating metals from the ores, the refining of these metals, and their preparation for use. In the other branch of metallurgy, the Physical Metallurgist deals with the content and structure of pure metals and their alloys. He specifies the methods that are to be used for converting the refined metal into a final product that has certain desired properties, such as strength and hardness. This change may be made by altering the internal structure of the metal through fabrication processes such as casting, rolling, and heat treatment.

Production — the commercial production of raw materials — is one of the fields in which the metallurgical engineer works.

Fabrication and Utilization, another of his fields, has been discussed above.

Research, the third field of the metallurgical engineer, involves studies for the improvement of production, fabrication, or utilization.

Characteristics of Metallurgical Engineers

The metallurgical engineer should have: (1) high ability in chemistry and physics; (2) some manual dexterity, which he will need in preparing specimens; (3) keen ability to observe, because he will make many physical tests; (4) no aversion or dislike for odors.

Professional Organization for Mining and Metallurgical Engineers

The American Institute of Mining and Metallurgical Engineers is the professional society for mining and metallurgical engineers. Its objectives as set forth in its articles of incorporation are: "To promote the arts and sciences connected with the economic production of the useful minerals and metals, and the welfare of those employed in these industries by all lawful means; to hold meetings for social intercourse and the reading and discussion of technical papers, and to circulate by means of publications among its members the information thus obtained, and to establish and maintain a place for meeting of its members, and a hall for the reading of papers and delivery of addresses, and a library of books relating to subjects cognate to the sciences and arts of mining and metallurgy."

The institute has seven classes of membership, of which Junior is the entering grade. It maintains two types of student relationship. One of these is the individual relationship with a student who pays a two dollar annual fee and is designated Student Associate. The other relationship is with organizations of students at approved schools. They are known as affiliated student societies or student chapters.